BROOKHAVEN NATIONAL LABORATORY

OCCUPATIONAL HEALTH AND SAFETY GUIDE

SPECIAL PRECAUTIONS FOR LOCATIONS CONTAINING FLAMMABLE ATMOSPHERES

4.12.0

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4.12.0

I. INTRODUCTION

Flammable liquids and gases are used in many of the Laboratory's operations. These may be released to the atmosphere either routinely or accidently. Because of the potential for serious fires or explosions, locations which may contain flammable atmospheres must be identified and clearly defined so that suitable controls, especially of potential ignition sources, can be developed, and equipment appropriate for use in the location selected.

II. SCOPE

A. This Guide is concerned with equipment requirements for locations where flammable gases or vapors are or may be present in air in quantities sufficient to produce ignitable mixtures. These locations are called "classified" locations, and are equivalent to "Class I" locations as defined in the ***National Electrical Code.*** This Guide provides the basis for determining:

1. Whether a location has sufficient potential for a flammable/air mixture to be classified.
2. The appropriate classification of the location.
3. The boundaries or extent of the location.
4. Equipment acceptable for use within the location.

B. This Guide is not applicable to locations which present explosion hazards because of combustible dusts or combustible fibers. (These are commonly known as Class II and III locations in the ***National Electrical Code).*** It is also not applicable to medical (patient care) facilities, which are specifically covered by other standards.

C. This Guide is to be used in conjunction with the ***National Electrical Code*** and other appropriate codes and standards. Much of this Guide is based upon National Fire Protection Association Recommended Practice ***497,*** "Class I Hazardous Locations for Electrical Installations in Chemical Plants" and Factory Mutual Data Sheet **5-1,** "Electrical Equipment in Hazardous (Classified) Locations." While the principals used in this Guide have been develped from electrical equipment applications, they are, in general, also applicable to other potential ignition sources.

D. Addition special precautions apply to locations containing flammable cryogenic liquids, which may be found in OH&S Guide 5.2.0, "Flammable Cryogenic Liquids."

III. DEFINITIONS

Adequate ventilation means that which is sufficient to prevent accumulation of quantities of vapor-air mixtures in concentrations greater than ***25%*** of the lower flammable limit. See Section IX for additional information on ventillation, and Appendix B for flammable limits.

Area is a two-dimensional space.

Location, Enclosure, Space, Zone are three-dimensional spaces.

Classified locations are those in which flammable gases or flammable vapors, are or may be present in air in quantities sufficient to produce ignitable mixtures. These locations are subdivided into two categories — Division **1** and Division 2.

Division 1 locations are likely to have flammable atmospheres present under normal conditions.

Division 2 locations are likely to have flammable atmospheres present only under abnormal conditions, such as the failure or rupture of equipment.

Group Classification. For purposes of testing and approving equipment, atmospheric mixtures are classified according to certain physical properties, such as: their ability to propagate flame through a flanged joint, their ignition temperatures, and in some cases, their ignition energies. Refer to Appendix B for specific chemicals by group.

Low, Moderate, and High Pressures. For the purposes of this Guide, pressures are considered "low" if less than 100 psi, "moderate" if between 100 and 500 psi, and "high" if greater than 500 psi.

IV. RESPONSIBILITIES

A. ***Department Chairmen/Division Heads**** of the user/designer are responsible for assuring that:

1. Any equipment to be installed in classified locations is in compliance with the requirements of this Guide.

2. A review committee is appointed in accordance with Section VIII.E for equipment designs that are not "approved" in accordance with Section VIII.D.

3. Adequate documentation, such as engineering drawings, specifications, and operating limits, sufficient to demonstrate equipment compliance with the provisions of this Guide are available to all interested parties and a copy submitted to the S&ES Division before construction or purchase.

B. ***Department Chairmen/Division Heads*** of the areas in whichequipment is to be used are responsible for assuring that:

1. Periodic reviews are conducted to determine locations where the provisions of this Guide are applicable.

2. Appropriate classifications of these locations are made.

3. The boundaries of classified locations are clearly delineated.

4. Equipment or other ignition sources inappropriate to classified locations is not in troduced in to these areas.

5. All users who may work in classified locations are familiar with this Guide.

C. Line Supervisors* are responsible for the direct implementation of this Guide. Specifically, they shall:

1. Periodically review their areas of responsibility to determine locations where the provisions of this Guide are applicable.

2. In consultation with the Fire Protection Engineer, assure that appropriate location classifications are made, that the boundaries of classified locations are clearly delineated, and that equipment or other ignition sources inappropriate to classified locations are not introduced.

3. Assure that all users who may work in classified locations are adequately trained in the provisions of this Guide.

4. Assure that Safety Coordinators of the facility containing classifiedlocations are aware of the precautions being taken.

D. ***Safeguards and Emergency Services (SES) Diuision*** staff are responsible for assisting in the implementation of this Guide. Specifically, the Fire Protection Engineer shall:

1. Review with line supervisors, potentially hazardous locations for appropriateness of classifications, boundaries, and equipment.

2. Assist design and review groups in the interpretation of the requirements of this Guide.

V. LOCATIONS NOT REQUIRING SPECIAL PRECAUTIONS

Experience has shown that the release of flammable gases or vapors from some operations and apparatus occurs so infrequently that it is not necessary to provide special precautions in the surrounding locations. For example, it is generally unnecessary to provide special precautions in the following locations:

1. Adequately ventilated locations where flammable liquids and gases are contained in suitable, well-maintained closed piping systems which include only properly protected pipe, valves, fittings, flanges, and meters. Exception: Systems where valves are frequently operated such that leakage at valve packings, etc., is to be expected.

2. Inadequately ventilated locations, where flammable liquids and gases are contained in suitable, properly protected, well maintained closed piping systems which are without valves, fittings, flanges, and similar accessories.

*For outside users, the Principal Investigator will assume or designate these responsibilities.

3. Locations containing fuel gas systems within the scope of, and installed, operated and maintained in accordance with the *National Fuel Gas Code,* NFPA 54, ANSI 2223.1.

4. Adequately ventilated locations where flammable liquids are properly stored (no dispensing or other usage) in containers allowed by, and the total quantities of liquids are within the limits of Tables I and II. OS&H Guide 4.10.2, "Flammable Liquids: Storage, Use and Disposal."

5. Adequately ventilated locations where flammable gases are properly stored (not connected for use) in DOT approved containers (i.e., cylinders), and the total capacity of the containers does not exceed 335 kg (735 lbs.) water capacity (e.g., nominal 135 kg, 300 lbs of LP-gas).

VI. LOCATIONS REQUIRING SPECIAL PRECAUTIONS

Each space, enclosure or zone should be considered individually in determining its classification. Considerable judgement is required to determine the classification in any given system. The past history of similar systems at BNL or elsewhere strongly influences the decision. Special considerations needs to be given to systems with valves which are frequently manipulated; experience with these valves indicates a greater potential for leakage than for valves which are rarely operated.

A. *Locutions Potentially Requiring Special Precautions*

Except as modified by Section V, a location potentially should be considered to require special precautions if any one of the following conditions exist:

1. Flammable liquids with flash points below 40°C (100°F) are likely to be present.

2. Flammable vapors or flammable gases are likely to be present.

3. Liquids having flash points above 40°C(100°F) are handled, processed, or stored at temperatures above their flash points.

B. *Division 1 Locations*

A location requiring special precautions should be classified "Division 1" if any one of the following conditions exist.

1. A flammable vapor or gas is likely to exist under normal operating conditions. Common examples at BNL are:

   (a) Flammable liquid storage rooms.

   (b) Locations above open containers of flammable liquids if their flash points are below 40°C, or they are heated to temperatures above their flash point.

   (c) Locations where vent fans, combustible gas analyzers and other equipment are intended to detect, disperse, or handle flammable vapors or gases.

   (d) Inside hoods where flammable liquids or gases are handled.

2. A flammable gas or vapor is likely to be present because of adjustments, maintenance, repairs, or anticipated leakage. Examples at BNL include:

   (a) Blockhouses, hoods, and other primary enclosures of liquid hydrogen-filled devices, where the device is filled from dewars and/or through nonpermanent transfer lines.

   (b) Liquefier and compressor rooms for liquid hydrogen where transfer operations are done inside the space.

3. A failure of process, storage, or other equipment is likely to cause an electrical failure (or any other ignition source) simultaneously with the release of flammable gas or liquid.

4. A flammable liquid or gas piping system is in an inadequately ventilated location, and the piping system contain valves, meters or screwed or flanged fittings that are likely to leak.

5. For flammable liquids or heavier than air vapors, the zone is below the surrounding elevation or grade such that liquids or vapors may accumulate.

6. For lighter than air gases, the zone is capable of accumulating quantities of gas above a potential release point.

C. ***Division*** 2 ***Locations***

A location requiring special precautions should be classified "Division 2" if any one of the following conditions exist:

1. **A** flammable liquid or gas system is in an inadequately ventilated location, and the system (containing valves, meters, or screwed or flanged fittings) is not likely to leak.

2. The flammable liquid or gas is being handled in an adequately ventilated location, and the liquid or vapor can escape only under abnormal conditions, such as failures of a gasket or packing. Examples at BNL include:

(a) Blockhouses, hoods, and other primary enclosures of liquid hydrogen-filled devices, where liquid hydrogen is totally contained in a permanent piping system.

(b) Liquefier and compressor rooms where the liquified flammable gas is totally enclosed in a permanent piping system and all transfer operations are done outside the space.

3. The location is adjacent to a Division 1 location, or the gas or vapor can be convected to the location through trenches, pipe, or ducts.

4. If positive mechanical ventilation is used, failure or abnormal operation of ventilating equipment would permit mixtures to build up to flammable concentrations.

VII. BOUNDARIES OF CLASSIFIED LOCATIONS

A. ***Determining Boundaries.*** After the potential classification of a space is determined from Section VI, its specific boundaries may be defined by applying the following principles, and the distances recommended in the diagrams in Appendix A, Figures 1 through **14.**

1. In the absence of walls, enclosures, or other barriers, and in the absence of air currents or similar disturbing forces, a gas or vapor will disperse in all directions, as governed by the vapor density and velocity (e.g., heavier-than-air vapors principally downward and outward, lighter-than-air vapors principally upward and outward). Thus, if the source of vapor were a single point, the horizontal area covered by the vapor would be a circle.

2. For heavier-than-air vapors released at or near grade level, the locations where potentially hazardous concentrations are most likely to be found are below grade; those at grade are next most likely; and, as the height above grade increases, the potential hazard decreases. In open locations away from the immediate point of release, freely drifting vapors from a source near grade seldom reach ignition sources at elevations more than two to three meters. For lighter-than-air gases the opposite is true; there is little or no potential hazard at and below grade, and greater potential hazard above grade.

3. Flammable liquids with a flash point between 40°C (100°F) and 60°C (140°F) should be considered as producing sufficient flammable vapors to produce vapor/air mixtures in the flammable range near the point of release when the liquid is handled, processed, or stored under conditions that may cause the temperature of the liquid to exceed its flash point.

4. Liquids having flash points at or above 60°C (140°F) may release vapor at their surface if heated above the flash point, but the extent of the hazardous zone will ordinarily be very small. These liquids seldom evolve sufficient quantities of vapor to render any significant zone hazardous.

5. Elevated or depressed sources of vapor release, or release of flammable vapor under pressure, may substantially alter the outline of the limits of the classified location. Also, a very mild breeze may extend these limits in the direction of air movement. However, a stronger breeze can so accelerate the dispersion **of** vapors that the boundaries of the classified location are greatly reduced. Experience has confirmed that the boundaries of exterior classified locations are normally only a small fraction of those that might theoretically be hazardous, based on a given rate of release.

6. There should be careful evaluation of prior BNL and general industry experience with the same or related types of installations. It is not enough to merely point to a potential source of vapor and proceed immediately with the the definition of the extent of the Division **1** and Division 2 locations. Where experience has indicated that a particular design concept is sound, a more hazardous classification for similar installations is not justified. Furthermore, it is conceivable that a location might be reclassified from Division **1** to Division 2, or from Division 2 to ordinary, based on experience.

7. Liquefied flammable gases are either cryogenic (e.g., liquid hydrogen) or compressed (e.g., propane in storage cylinders), or both. These gases, while released as liquids, readily vaporize, creating large volumes of heavier than air gases. When released at or near grade, these gases may travel along the ground for long distances especially if air currents do not assist diffusion. When these gases are released at some distance above grade level, or upward at substantial velocity, diffusion is faster and the spread from point of release is usually much less.

8. The volume of liquid or gas that may be released is of extreme importance in determining the extent of a classified location, and it is this consideration which necessitates the greatest application of sound judgment. (One should not lose sight of the purpose of this judgment, i.e., the location is classified solely for the installation of electrical equipment or other ignition sources.) For example, a gland leaking a quart a minute (360 gallons per day) certainly could not be commonplace; yet, if a quart bottle were emptied every minute outdoors, the zone made hazardous would be very hard to locate with a combustible gas detector. Correctly evaluated, an installation is often found to be a multiplicity of Division 1 locations of extremely limited extent surrounded by somewhat larger Division 2 zones.

B. ***Boundary Identification.*** The boundaries of classified areas are to be clearly identified with physical barriers, floor stripping, etc. Signs are to be posted which detail the classification of the location, the person or group responsible for the area, and appropriate safety precautions, such as:

1. No smoking or open flames.

2. Controls on introduction of ordinary equipment.

3. Work permits.

C. Use ***of Diagrams***

1. The diagrams in Appendix A show classified zones surrounding typical sources of flammable liquids, vapors, and gases. Some of the illustrations apply to a single source; others apply to an enclosed space or to an operating unit.

2. A location may have many interacting sources of flammable liquid, vapor, or gas, including pumps, compressors, exchangers, vessel flanges, sampling stations, and operating and control valves. Select the diagram or diagrams which apply to each source or condition. Determine the applicable divisions, their extent, and their layout in light of the local environmental conditions. A layout of each classified zone based on the interaction of individual sources may be desirable.

3. Individual classification of a great number of sources in a location may be neither feasible nor economical. Classification of an entire building or location as a single zone should be considered only after evaluation of the extent and interaction of various sources and zones within the location, or adjacent to it.

VIII. BASIC EQUIPMENT REQUIREMENTS

A. *Design Based Upon Division Classification*

After determining the location classification (Section VI), and the boundaries of the classification (Section VII), equipment design is based upon the specific division classification in which the equipment is located.

1. Division l. Equipment appropriate to Division **1** locations is designed so that neither normal operation nor failure of any portion of the equipment will provide an ignition source (such as released sparks, flames, or hot gases; or have sufficiently high surface temperatures to ignite the surrounding atmosphere). Equipment appropriate to Division **1** locations is always suitable for Division 2 locations.

2. Division 2. Equipment appropriate to Division 2 locations is designed so that its normal operation does not provide a source of ignition. Complete protection is not provided against ignition due to equipment faults on the assumption that equipment breakdowns resulting in ignition sources occur rarely and are unlikely to coincide with the presence of flammable mixtures. Where equipment failure and release of flammable vapors are likely to occur simultaneously, the equipment should be appropriate to Division **1** locations.

B. ***Minimize Equipment in Classified Locations***

Wherever possible, equipment that is a potential source of ignition should be located outside of classified locations. Ordinary equipment is usually less expensive, and easier to maintain with proper personnel protection and minimum service interruption.

C. ***Appropriate Equipment for Classified Locations***

1. Where a location has been determined to be classified, equipment provided in the location shall meet both of the following two standards:

a. It is to be appropriate for the Division **(1** or 2),

b. It is to be appropriate for the Group (A, B, C, or D, refer to Appendix B).

2. To achieve this requirement, equipment design may be any one of the following:

a. explosion-proof;

b. purged and pressurized;

c. intrinsically safe; or

d. non-incendive (Division 2 only).

3. The kinds of commercial electrical equipment recommended for classified locations are shown in Table 1, page 9.

D. ***Approved Equipment***

If available, Underwriters Laboratories- or Factory Mutual-approved equipment should be used. When UL-or FM-approved equipment is not available, equipment listed, labeled, or approved by another recognized testing laboratory is preferable (e.g., U.L. of Canada). If this is not possible, equipment certified in writing by the manufacturer to have passed equivalent tests may be used, after consultation with the Fire Protection Engineer.

Note: Electrical equipment appropriate for classified locations is specifically approved for either Division **1** or Division **2** locations and for one or more atmosphere Groups (A, B, C, D). The manufacturer labels the equipment to show the class, division, group, and operating temperature or temperature range for which it is approved. The Fire Protection Engineer has available the following Underwriters Laboratories and Factory Mutual approval publications:

UL Hazardous Location Equipment Directory FM Approval Guide

E. ***Unapproved Equipment***

Where unapproved equipment is needed, engineering solutions shall be reviewed by a committee appointed by the Department Chairman/Division Head to assure equivalent safety.

Note: Flammable cryogenic liquid system designs are required to be submitted to the Cryogenic Safety Committee for review of both the equipment design and integration within a building or laboratory, in accordance with OH&S Guide 5.2.0, "Flammable Cryogenic Liquids."

IX. EQUIPMENT CATEGORIES

Equipment design appropriate to classified locations falls in to four categories: explosion-proof, purged, intrinsically safe, and non-incendive.

A. ***Explosion-proof***

Explosion-proof means that the device has an enclosure which is capable of withstanding an internal explosion of a specified gas or vapor Group without igniting a similiar external mixture. Also, the maximum external

surface temperatures of the equipment are below the ignition temperature of the group. Only "approved" equipment, installed in accordance with its listing, can be considered explosion-proof.

B. Purged Enclosures

1. To purge a space means that air or inert gas is supplied at sufficient flow and positive pressure to reduce the concentration of any flammable gas or vapor to an acceptably safe level, and to maintain this safe level. Because of the many specific requirements to safely purge enclosures, all such designs are to be specifically reviewed by the BNL Fire Protection Engineer.

2. The three types of purging generally used for enclosures are Types X, Y, and Z.

a. Type X purging reduces the classification within an enclosure from Division 1 to ordinary. Therefore, there are no special equipment requirements within the enclosure.

b. Type Y purging reduces the classification within an enclosure from Division 1 to Division 2. Therefore, all equipment within the enclosure must be approved for Division 2.

c. Type Z purging reduces the classification within an enclosure from Division 2 to ordinary. Therefore, there are no special equipment requirements within the enclosure.

3. Purged equipment, when not specifically approved, is acceptable if it meets the requirements of "Purged and Pressurized Enclosures for Electrical Equipment," NFPA 496.

Note: The provisions of this section apply to enclosures where the source of flammable gas or vapor is external to the enclosure. Purging arrangements where the source of flammable gas or vapor is interior to the enclosure are being evaluated and will be included in future editions of the Guide.

C. Intrinsically Safe Equipment

1. Intrinsically safe equipment and wiring are incapable of releasing sufficient energy under both normal and specific fault conditions to ignite a specific flammable (group) mixture in its most easily ignited concentration. Intrinsically safe apparatus is suitable for both Division 1 and Division 2 locations. The intrinsically safe apparatus is satisfactory for use in the specified atmosphere without special enclosures.

2. Equipment, when not specifically approved, is acceptable if it meets the requirements of "Intrinsically Safe Apparatus and Associated Apparatus For Use in Class I, II, and III, Division 1 Hazardous Locations," NFPA 493.

D. ***Non-Incendive Equipment***

1. Non-incendive equipment and wiring are incapable of releasing sufficient energy during *normal* operating conditions to ignite a specific flammable (group) mixture. Non-incendive equipment is satisfactory for use in Division 2 locations but not Division 1 locations.

2. Electrical equipment approved as non-incendive is listed in Factory Mutual's Approval Guide. Underwriters Laboratories does not list non-incendive equipment. Equipment, when not specifically approved, is acceptable if it meets all the "normal operation" requirements of "Intrinsically Safe Apparatus and Associated Apparatus for use in Class I, II, and III, Division 1 Hazardous Location," NFPA 493.

X. VENTILATION

A. Any building, room, or space which is substantially open and free from obstruction to the natural passage of air through it, vertically or horizontally, is considered to be adequately ventilated. Such locations may be roofed over with either no walls or enclosed on one side.

B. An enclosed or partly enclosed space is considered as adequately ventilated if it is provided with artificial ventilation in an amount equivalent to natural ventilation under low-wind-velocity conditions and there are adequate safeguards against the failure of the ventilation equipment. In general, this means that the space is to be normally and continously mechanically ventilated at a rate of not less than one cubic foot per minute per square foot of solid floor area. Make-up air is to be introduced in such a manner as not to limit or short circuit the ventilation, especially near the floor for heavier than air vapors or gases, or near the ceiling for lighter than air vapors or gases. Ventilation is to be arranged to include all locations (e.g., pits) where flammable vapors or gases can collect.

Table 1

Table 1. Equipment Recommended for Locations Containing Flammable Vapors or Gases (Class 1)*

	Division 1	Division 2
Wiring	Threaded rigid metal conduit or Type MI cable. Explosionproof boxes and fittings. Use seals to prevent passage of gases, vapors, or flames through conduit from one portion of electrical installation to another.	Threaded rigid metal conduit, enclosed gasketed busways, or Type MI, MC, ALS. CS, TC, or SNM cable. No seals required except where explosionproof equipment is necessary and conduit leaves hazardsus area. Wiring, which under normal conditions cannot release sufficient energy to ignite a specific hazardous atmospheric mixture can be accepted using any of the methods suitable for wiring in ordinarv locations.
Switches, circuit breakers, and motor controllers	Install in an enclosure approved as a complete assembly for Class I Division 1 locations. (Enclosures approved for Class I, Division 1 locations include explosionproof and purged and pressurized enclosures.)	Same as Division 1, unless general purpose enclosures are provided and the interruption of current occurs in hermetically sealed chambers or the contacts are oil-immersed. (General-purpose enclosures are acceptable for isolating or disconnecting switches without fuses and not intended to interrupt current.
Fuses	Install in an enclosure approved as a complete assembly for Class I, Division 1 locations. (Enclosures approved for Class I. Division 1 locations include explosionproof and purged and pressurized enclosures.)	Install in an enclosure approved for Class I. Division 1 locations, for fuses protecting motors, appliances. and portable lamps. General purpose enclosures are acceptable for these fuses if the operating element of the fuse is oil-immersed or in hermetically sealed chamber. (General-purpose enclosures are acceptable for fuses on circuits to fixed lamps.)
Receptacles and attachment plugs	Polarized type approved for Class I locations, having provision for connection to grounding conductor of flexible cord.	Same as Division 1
Motors and generators	Approved for Class I locations, or totally enclosed type supplied with positive pressure ventilation from a source of clean air, or totally enclosed inert gas filled type supplied with a source of inert gas pressure the enclosure.	Enclosure approved for Class I location for rotating electrical machines employing sliding contacts, centrifugal or other switches or integral resistors, unless such contacts, switches, and resistors have enclosures approved for Class I. Division 1 locations. Open polyphase squirrel-cage induction motors without brushes or switches are acceptable. (Total enclosed polyphase squirrel-cage induction motors are preferrable for new installations.)
Lighting fixtures	Fixed and portable units approved as complete assembly for Class I, Division 1 locations. Fixtures should have guards surrounding the globes or be located so as not to be subject to physical damage.	Fixed enclosed gasketed globes or other effective protective means where (a) flammable liquids are in the open, or (b) sparks or hot metal from lamps or fixtures might ignite local concentration of flammable vapors or gases. Use lamps of a size or type that do not reach surface temperatures in excess of 80% of the ignition temperature (°C) of the gas or vapor involved: or use fixed fixtures approved as complete assembly for Class I, Division 1 locations. Other fixed lighting units may be ordinary open type without switches, starters, or control equipment. Fixtures for fixed lighting should have guards or be located so as not to be subject to physical damage. Portable lamps to be approved as complete assembly for Class I. Division 1 locations.

*Wherever possible, locate electrical equipment outside of hazardous areas. More specific details are given in Article 501 of the *National Electrical Code. See* the *National Electrical Code* for details on equipment not covered in Table 1.

Table 1 (continued)

Table 1. Equipment Recommended for Locations Containing Flammable Vapors or Gases (Class 1)*

	Division 1	Division 2
Transformers and capacitors	Install units containing either flammable or non-flammable liquid in approved vaults having no openings to hazardous areas, or use units approved for Class I locations for those that do not contain a liquid that will burn.	Install according to rules for nonhazardous locations.
Meters, relays, and instruments	Enclosure approved for Class I. Division 1 locations, or intrinsically safe equipment. (Enclosures approved for Class I, Division 1 locations include explosion-proof and purged and pressurized enclosures.)	Equipment containing make-and-break contacts in enclosures approved for Class I. Division 1 locations. General purpose enclosures are acceptable if current interrupting contacts are (a) oil-immersed, or (b) hermetically sealed, or (c) in circuits that under normal conditions do not release sufficient energy to ignite a specific hazardous atmospheric mixture, i.e., are non-incendive. Equipment, such as transformer windings, solenoids, and other windings that do not contain sliding or make-and-break contacts acceptable in genera1 purpose enclosures.

APPENDIX A

Boundaries of Classified Locations

All figures are reprinted by permission from NFPA 497, "Recommended Practice for Classification of Class I Hazardous Locations for Electrical Installations in Chemical Plants," Copyright' 1975, National Fire Protection Association, Boston, MA.

Figure 1. Pumps and similar devices handling flammable liquids at low and moderate pressures, indoors with adequate ventilation.

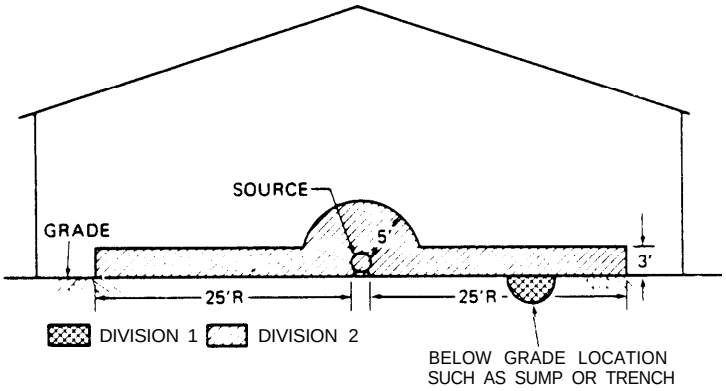


Figure 2. Pumps and similar devices handling flammable liquids at low pressures, indoors above grade in a building with adequate ventilation.

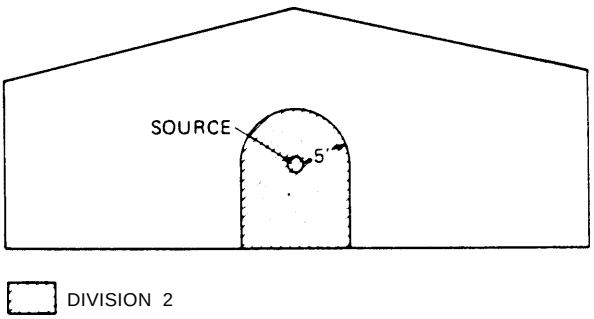


Figure 3. Pumps and similar devices handling flammable liquids at moderate pressures, indoors with adequate ventilation and with a pierced wall or full wall opening.

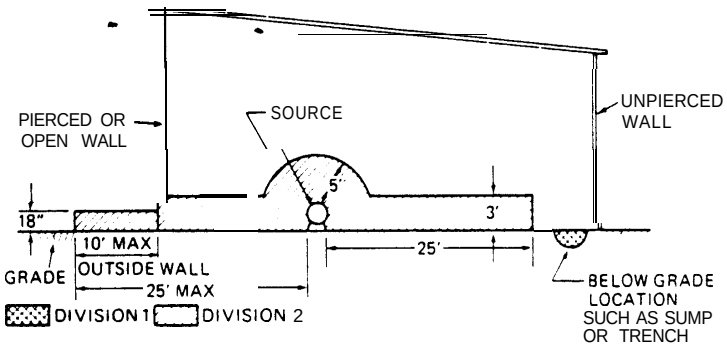


Figure 4. Pumps and similar devices handling flammable liquids at moderate pressures, indoors with inadequate ventilation and with a pierced wall or full wall opening.

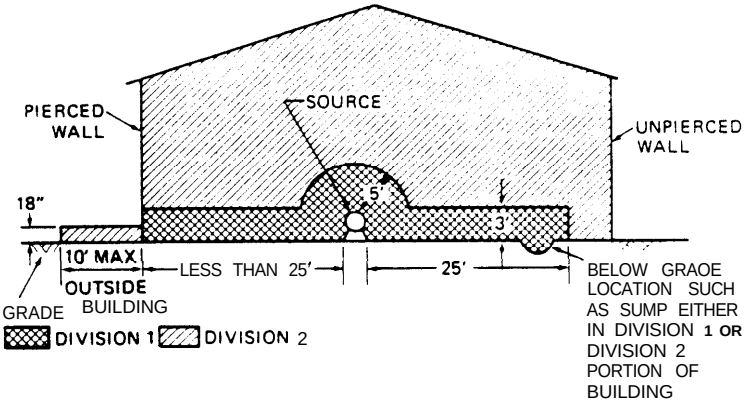


Figure 5. Pumps and similar devices handling flammable liquids at high pressures or compressed liquefied flammable gases, in an equipment shelter with inadequate ventilation.

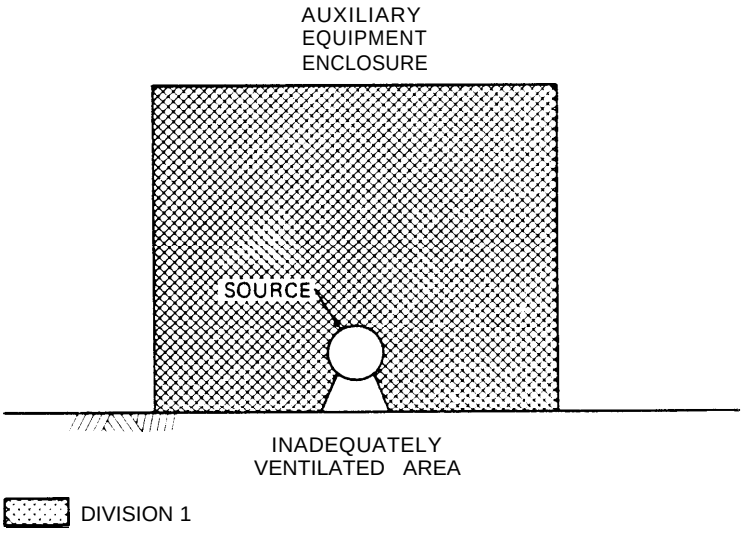


Figure 6. Pumps and similar devices handling flammable liquids or compressed liquefied flammable gases at high pressures, indoors with adequate ventilation.

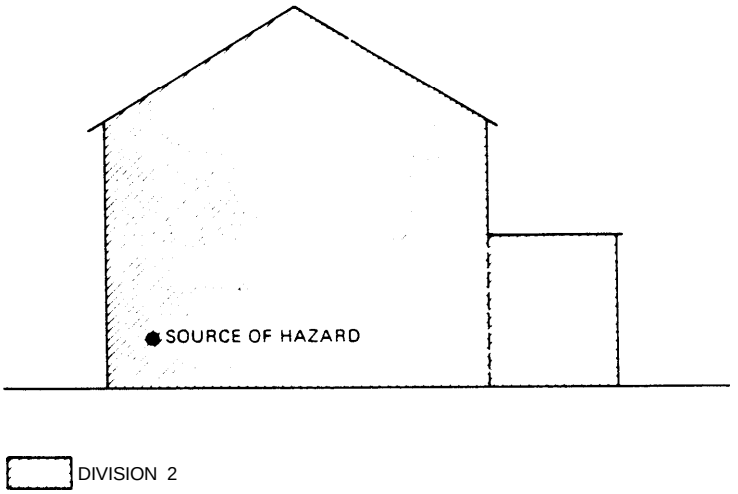


Figure 7. Flammable liquids handled at high pressures, with source of hazard located at or above grade within an adequately ventilated process location. (See API RP 500A — April 1966.)

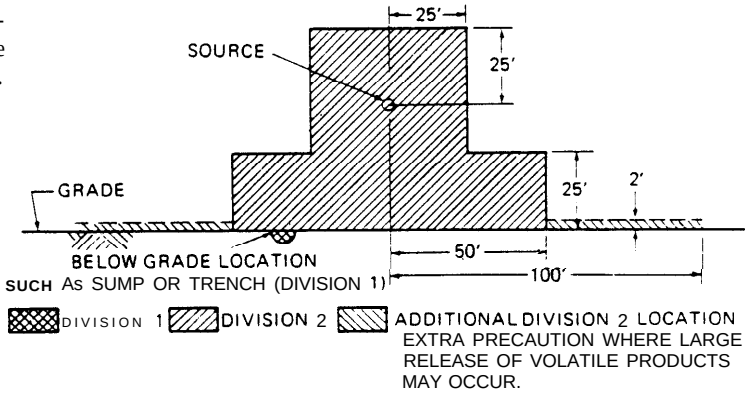
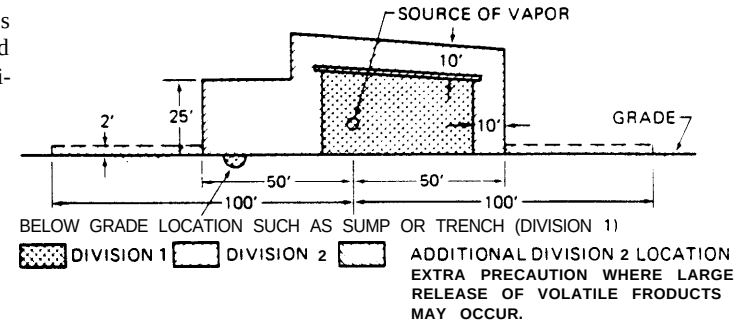


Figure 8. Indoor process area, flammable liquids handled at high pressures, with source of hazard located above grade within an inadequately ventilated location. (See API RP 500A — April 1966.)



Apply horizontal **clearances** of **50 ft** from source of vapor or 10 ft beyond perimeter of building, whichever is greater; except beyond **unpierced** vaportight walls, the zone is classified nonhazardous.

Figure 9. Open tanks or tanks with hatches normally open. Also, dispensing stations, open centrifuges, plate and frame filters, vacuum filters, and surfaces of open equipment.

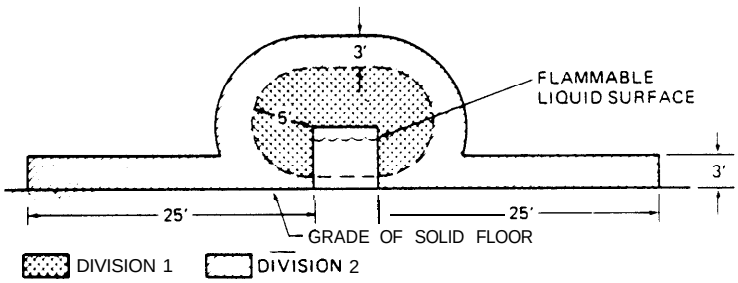
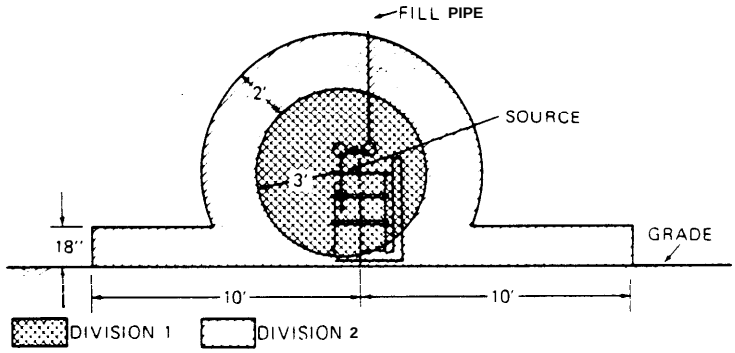


Figure 10. Drum and container loading outdoors, or indoors with adequate ventilation. (See NFPA No. 30, Table 6-l.)



4.12.0

Figure 11. Ventilated spray booth or hood interlocked so as to make the equipment inoperative when the ventilating equipment is off. (See NFPA No. 33, 4-7.2)

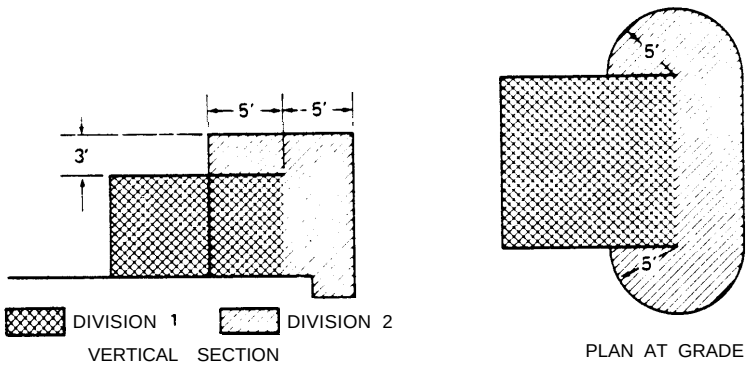


Figure 12. Liquid hydrogen systems at consumer sites, located outdoors or in building. (See NFPA No. 50B, Article 49, Electrical Systems.)

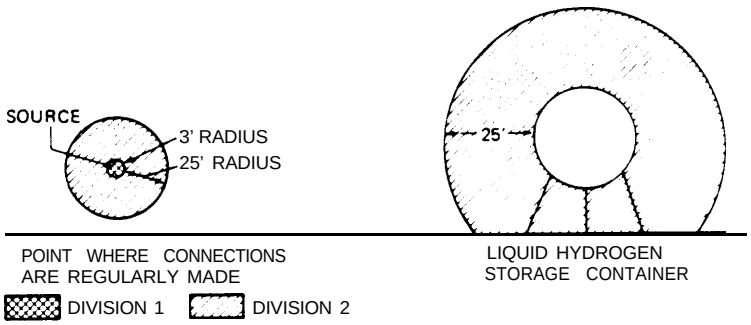


Figure 13. Gaseous hydrogen at consumer sites. (See NFPA No 50A.)

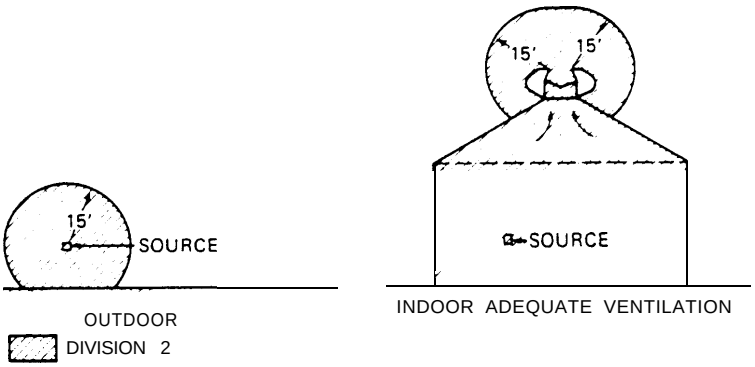
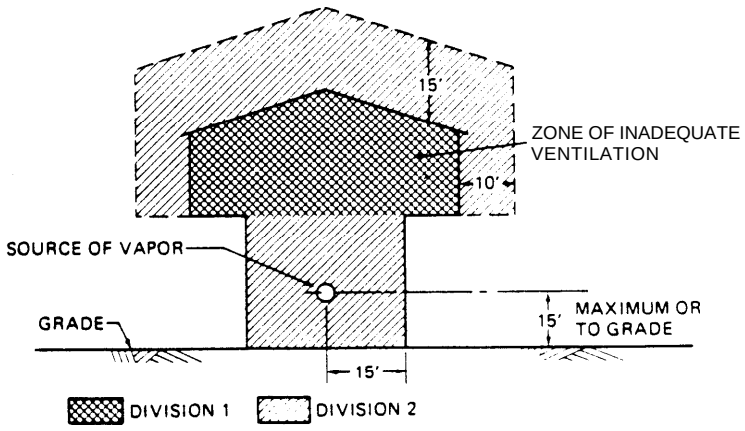


Figure 14. Lighter-than-air gas compressor located within an inadequately ventilated location. (See API RP 500A — April 1966.)



APPENDIX B

Classification of Vapors and Gases

The material in this Appendix has been obtained from NFPA 497M-1983, "Manual for Classification of Gases. Vapors and Ducts for Electrical Equipment in Hazardous (Classified) Locations" and other NFPA Sources.

The materials and their group classifications listed in Tables B-l, B-2 and B-3 and have been culled from Matrix of Combustion-Relevant Properties and Classification of Gases, Vapors, and Selected Solids, NMAB 353-1, published by the National Academy of Sciences. Those materials whose group classifications are marked with asterisks were previously assigned group classifications based on tests conducted in the Westerberg Apparatus at Underwriters Laboratories Inc. (See "An Investigation of Fifteen Flammable Gases or Vapors with Respect to Explosion-Proof Electrical Equipment," UL Bulletin of Research No. 58 and subsequent Bulletins Nos. 58A and 58B.) All other materials were assigned group classifications based on analogy with tested materials and on chemical the classifications of these latter materials represent the best judgement of two groups of experts, it is conceivable that the group classification of any particular untested material may be incorrect. In certain instances, therefore, it may be advisable to submit an untested material to a qualified testing laboratory for verification of the assigned group classification.

Autoignition temperatures are the lowest value for each materials as listed in NFPA 325M, "Fire Hazard Properties of Flammable Liquids, Gases and Volatile Solids," or as-reported in an article by Hilado, C. J. and Clark, S. W., in Chemical Engineering, September 4, 1972.

Flammable limits are as listed in NFPA 325M-1977, "Fire Hazard Properties of Flammable Liquids, Gases, and Volatile Solids."

Table B-l

Flammable Gases and Vapors of Liquids Having Flash Points Below 40°C(100°F)

Table B-l lists those materials that are either flammable gases or vapors of flammable liquids, as defined by NFPA 321, "Standard on Basic Classification of Flammable and Combustible Liquids." In general, these gases or vapors form ignitible or explosive mixtures with air at ambient temperatures. Thus, special precautions are normally required.

	Auto Ignition Temperature			Flammable Range	
Material	Group	°F	°C	Lower %	Upper %
Acetaldehyde	C*	347	175	4	60
Acetone	D*	869	465	2.1	13
Acetonitrile	D	975	524	3	17
Acetylene	A*	581	305	2.5	100
Acrolein (inhibited)	B(C)*'	455	2 3 5	2.8	31
Acrylonitrile	D*	898	481	3.0	17
Ally1 Alcohol	C*	713	378	2.5	18
Ally1 Chloride	D	905	485	—	—
Ammonia	D*[2]	928	498	16	25
n-Amyl Acetate	D	680	360	1.1	7.5
sec-Amyl Acetate	D	—	—	—	—
Benzene	D*	1040	560	1.3	7.1

Table B-l (Cont'd)

Material	Group	Auto Ignition Temperature °F	Auto Ignition Temperature °C	Flammable Range Lower %	Flammable Range Upper %
1,3-Butadiene	B(D)*'	788	420	2.0	12
Butane	D*	550	288	1.6	—
1-Butanol	D*	650	343	1.7	11.2
2-Butanol	D*	761	405	1.7	9.8
n-Butyl Acetate	D*	790	421	1.7	7.6
iso-Butyl Acetate	D*	790	421	—	—
set-Butyl Acetate	D	—		1.7	9.8
Butylamine	D	594	312	1.7	9.8
Butylene	D	725	385	1.6	10.0
Butyl Mercaptan	C	—	—	—	—
n-Butyraldehyde	C*	425	218	1.9	12.5
Carbon Disulfide	—*[2]	194	90	1.3	50.0
Carbon Monoxide	C*	1128	609	12.5	74
Chloro benzene	D	1099	593	1.3	9.6
Chloroprene	D		—	4.0	20.0
Crotonaldehyde	C*	450	232	2.1	15.5
Cyclohexane	D	473	245	1.3	8
Cyclohexane	D	471	244	—	—
Cyclopropane	D*	938	503	2.4	10.4
1,1-Dichloroethane	D	820	438	5.6	—
1,2-Dichloroethylene	D	860	460	9.7	12.8
1,3-Dichloropropene	D	—	—	5.3	14.5
Dicyclopentadiene	C	937	503	—	—
Diethyl Ether	C*	320	160	1.9	36
Diethylamine	C*	594	312	1.8	10.1
Di-isobutylene	D*	736	391	0.8	4.8
Di-isopropylamine	C	600	316	1.1	7.1
Dimethylamine	C	752	400	2.8	14.4
1,4-Dioxane	C	356	180	2.0	22
Di-n-propylamine	C	570	299	—	—
Epichlorohydrin	C*	772	411	3.8	21
Ethane	D*	882	472	3.0	12.5
Ethanol	D*	685	363	3.3	19
Ethyl Acetate	D*	800	427	2	11.5
Ethyl Acrylate (inhibited)	D*	702	372	1.4	14
Ethylamine	D*	725	385	3.5	14
Ethyl Benzene	D	810	432	1.0	6.7
Ethyl Chloride	D	966	519	3.8	15.4

Table B-l (Cont'd)

Material	Group	Auto Ignition Temperature °F	Auto Ignition Temperature °C	Flammable Range Lower %	Flammable Range Upper %
Ethylene	C*	842	450	2.7	36.0
Ethylenediamine	D*	725	385	4.2	14.4
Ethylene Dichloride	D*	775	413	6.2	16
Ethyle nimine	C*	608	320	3.6	46
Ethylene Oxide	B(C)*'	804	429	3.6	100
Ethyl Formate	D	851	429	2.8	16
Ethyl Mercaptan	C*	572	300	2.8	18
n-Ethyl Morpholine	C	—	—	—	—
Formaldehyde (Gas)	B	795	429	7.0	73
Gasoline	D*	536-880	280-471	0.8	4 (approx.)
Heptane	D*	399	204	1.1	6.7
Heptene	D	500	260	—	—
Hexane	D*	437	225	1.1	7.5
2-Hexanone	D*	795	424	—	8
Hexenes	D	473	245	—	—
Hydrogen	B*	752	400	4	75
Hydrogen Cyanide	C*	1000	538	5.6	40
Hydrogen Selenide	C	—	—	—	—
Hydrogen Sulfide	C*	500	260	4	44
Isoamyl Acetate	D	680	360	1	7.5
Isoamyl Alcohol	D	662	350	1.2	9
Isobutyl Acrylate	D	800	427	1.3	10.5
Isobutyraldehyde	C	385	196	—	—
Isoprene	D*	743	395	1.5	8.9
Isopropyl Acetate	D	860	460	1.8	8
Isopropylamine	D	756	402	—	—
Isopropyl Ether	D*	830	443	1.4	7.9
Isopropyl Glycidyl Ether	C	—	—	—	—
Liquefied Petroleum Gas	D	761-842	405-450	5	14 (approx.)
Manufactured Gas (containing more than 30% H_2 by volume)	B*	—	—	—	
Mesityl Oxide	D*	652	344	1.4	7.2
Methane	D*	999	537	ɔ	15
Methanol	D*	725	385	6	36
Methyl Acetate	D	850	454	3.1	16
Methylacetylene	C*	—	—	1.7	—

Table B-l (Cont'd)

Material	Group	Auto Ignition Temperature °F	Auto Ignition Temperature °C	Flammable Range Lower %	Flammable Range Upper %
Methylacetylene-Propadiene (stabilized)	C	—	—	—	—
Methyl Acrylate	D	875	468	2.8	25
Methylamine	D	806	430	4.9	20.7
Methylcyclohexane	D	482	250	1.2	6.7
Methyl Ether	C*	662	350	3.4	27.0
Methyl Ethyl Ketone	D*	759	404	1.7	11.4
Methyl Formal	C*	460	238	—	—
Methyl Formate	D	840	449	4.5	23
Methyl Isobutyl Ketone	D*	840	440	1.2	8.0
Methyl Isocyanate	D	994	534	5.3	26
Methyl Mercaptan	C	—	—	3.9	21.8
Methyl Methacrylate	D	792	422	1.7	8.2
2-Methyl-1-Propanol	D*	780	416	1.7	10.6
2-Methyl-2-Propanol	D*	892	478	2.4	8.0
Monomethyl Hydrazine	C	382	194	2.5	92
Naphtha (Petroleum)	D*[4]	550	288	0.9	6.7 (approx.)
Niroethane	C	778	414	3.4	—
Nitromethane	C	785	418	7.3	—
Nonane	D	401	205	—	—
Nonene	D	—	—	—	—
Octane	D*	403	206	1.0	6.5
Octene	D	446	230	—	—
Pentane	D*	470	243	1.5	7.8
1-Pentanol	D*	572	300	1.2	10.0
2-Pentanone	D	846	452	1.5	8.2
1-Pentene	D	527	275	1.5	8.7
Propane	D*	842	450	2.1	9.5
1-Propanol	D*	775	413	13.7	—
2-Propanol	D*	750	399	2	12.7
Propionaldehyde	C	405	207	2.6	17
n-Propyl Acetate	D	842	450	1.7	8
Propylene	D*	851	455	2	11.1
Propylene Dichloride	D	1035	557	3.4	14.5
Propylene Oxide	B(C)*	840	449	2.8	37.0
n-Propyl Ether	C*	419	213	—	—

Table B-l (Cont'd)

Material	Group	Auto Ignition Temperature °F	Auto Ignition Temperature °C	Flammable Range Lower %	Flammable Range Upper %
Propyl Nitrate	B*	347	175	2	100
Pyridine	D*	900	482	1.8	12.4
Styrene	D*	914	490	1.1	6.1
Tetrahydrofuran	C*	610	321	2	11.8
Toluene	D*	896	480	1.2	7.1
Triethylamine	C*	—	—	1.2	8.0
Tripropylamine	D	—	—	—	—
Turpentine	D	488	253	0.8	—
Unsymmetrical Dimethyl Hydrazine (UDMH)	C*	480	249	2	95
Valeraldehyde	C*	432	222	—	—
Vinyl Acetate	D*	756	402	2.6	13.4
Vinyl Chloride	D*	882	472	3.6	33
Vinylidene Chloride	D	1058	570	7.3	16.0
Xylenes	D*	867-984	464-529	1	7 (approx.)

Notes to Table B-l

*Material has been classified by test.

'If equipment is isolated by sealing all conduit 1/2 in. or larger, in accordance with Section 510-5(a) of NFPA 70, *National Electrical Code,* equipment for the group classification shown in parentheses is permitted.

'For classification of areas involving ammonia, see "Safety Code for Mechanical Refrigeration," ANSI ASHRAE 15, and "Safety Requirements for the Storage and Handling of Anhydrous Ammonia," ANSI CGA G2.1.

[3] Certain chemicals may have characteristics that require safeguards beyond those required for any of the above groups. Carbon disulfide is one of these chemicals because of its low autoignition temperature and the small joint clearance to arrest its flame propagation.

'Petroleum naphtha is a saturated hydrocarbon mixture whose boiling range is 20° to 135°C. It is also known as benzene, ligroin, petroleum ether, and naphtha.

Table B-2

Flammable Liquids Having Flash Points 40°C(100°F) on Greater, but less than 60°C (140°F)

Table B-2 lists vapors of Class II combustible liquids, as defined by NFPA 321, "Standard on Basic Classification of Flammable and Combustible Liquids." In general, these materials do not form flammable mixtures with air at ambient temperatures unless heated above their flash points. Special precautions are normally required only under such circumstances.

		Auto Ignition Temperature		Flammable Range	
Material	Group	°F	°C	Lower %	Upper %
Acetic Acid	D*	867	464	4.0	19.9
Acetic Anhydride	D	600	316	—	10.3
Acrylic Acid	D	820	438	3.0	—
Ally1 Glycidyl Ether	B(C)	—	—	—	—
t-Butyl Acetate	D	—	—	—	—
n-Butyl Acrylate (inhibited)	D	559	293	1.5	9.9
n-Butyl Glycidyl Ether	B(C)	—	—	—	—
Cumene	D	795	424	0.9	6.5
Cyclohexanone	D	473	245	1.1	9.4
p-Cymene	D	81'7	436	0.7	5.6
Decene	D	455	235	—	—
Diethyl Benzene	D	743-842	395-450	—	—
Di-isobutyl Ketone	D	745	396	0.8	7.1
Dimethyl Formamide	D	833	455	2.2	15.2
Dipentene	D	458	237	0.7	6.1
Ethyl sec-Amyl Ketone	D	—	—	—	—
Ethyl Butanol	D	—	—	—	—
Ethyl Butyl Ketone	D	—	—	—	—
Ethylene Chlorohydrin	D	797	425	4.9	15.9
Ethylene Glycol Monoethyl Ether	C	455	235	1.7	15.6
Ethylene Glycol Monoethyl Ether Acetate	C	715	379	1.7	—
Ethylene Glycol Monomethyl Ether	D	545	285	2.3	24.5
2-Ethyldexaldehyde	D	375	191	0.85	7.2
Ethyl Silicate	D	—	—	—	—
Formic Acid (90%)	D	813	434	18	57
Fuel Oils	D	410-765	210-407	0.7	5 (approx.)
set-Hexyl Acetate	D	—	—	—	—
Hydrazine	C	74-518	23-270	2.9	98
Iso-octyl Aldehyde	C	387	197	—	—
Kerosene	D	410	210	0.7	5

Table B-2 (Cont'd)

Material	Group	Auto Ignition Temperature F	Auto Ignition Temperature C	Flammable Range Lower %	Flammable Range Upper %
Methyl Amyl Alcohol	D	—	—	7.0	5.5
Methyl n-Amyl Ketone	D	740	393	1.1	7.9
o-Methylcyclohexanone	D	—	—	—	—
alpha Methyl Styrene	D	1066	574	1.9	6.1
Morpholine	C*	590	310	2.0	11.2
Naphtha (Coal Tar)	D	531	277	—	—
1-Nitropropane	C	789	421	2.2	—
2-Nitropropane	C*	802	428	2.6	11.0
Propionic Acid	D	870	466	2.9	12.1
Tetramethyl Lead	C	—	—	—	—

Notes to Table B-2

*Material has been classified by test.

[1] If equipment is isolated by sealing all conduit 1/2 in. or larger, in accordance with Section 501-5(a) of NFPA 70, *National Electrical Code,* equipment for the group classification shown in parentheses is permitted.

Table B-3

Flammable Liquids Having Flash Points 60°C (140°F) or Greater, but Less Than 93°C (200°F)

Table B-3 lists vapors of Class IIIA combustible liquids, as defined by NFPA321, 'Standard on Basic Classification of Flammable and Combustible Liquids." These materials do not form flammable mixtures with air at ambient temperatures unless they are heated above their flash points. Furthermore, the vapors from such heated liquids cool rapidly in air. Special precautions are required only in the space in which the temperature of the vapor is actually above the flashpoint of the liquid or in the space in which mists may condense in ignitible concentrations as vapors cool.

Experience has shown that Class IIIB combustible liquids (flash point above 93°C (200°F)) are seldom ignited by properly installed and maintained general purpose electrical equipment. Therefore, Class IIIB liquids are not included in the tables, and special precautions are usually not required.

		Auto Ignition Temperature		Flammable Range	
Material	Group	°F	°C	Lower %	Upper %
Acetone Cyanohydrin	D	1270	688	2.2	12.0
Adiponitrile	D	—	—	—	—
Aniline	D	1139	615	1.3	11
Benzyl Chloride	D	1085	585	1.1	—
n-Butyl Formal	C	—	—	—	—
t-Butyl Toluene	D	—	—	—	—
n-Butyric Acid	D	830	443	2.0	10.0
Chloroacetaldehyde	C	—	—	—	—
1-Chloro-1-Nitropropane	C	—	—	—	—
Cresol	D	1038-1110	559-599	1.1	—
Cyclohexanol	D	572	300	—	—
n-Decaldehyde	C	—	—	—	—
n-Decanol	D	550	288	—	—
Diacetone Alcohol	D	1118	603	1.8	6.9
o-Dichiorobenzene	D	1198	647	2.2	9.2
1,1-Dichloro-1-Nitroethane	C	—	—	—	—
Diethylaminoethanol	C	—	—	—	—
Diethylene Glycol Monobutyl Ether	C	442	228	0.85	24.6
Diethylene Glycol Monomethyl Ether	C	465	241	—	—
N-n-Dimethyl Aniline	C	700	371	—	—
Dimethyl Sulfate	D	370	188	—	—
Dipropyiene Glycol Methyl Ether	C	—	—	—	—
Dodecene	C	491	255	—	—
Ethylene Glycol Monobutyl Ether	C	460	238	1.1	12.7
Ethylene Monobutyl Ether Acetate	C	645	340	0.88	8.54

Table B-3 (Cont'd)

Material	Group	Auto Ignition Temperature °F	Auto Ignition Temperature °C	Flammable Range Lower %	Flammable Range Upper %
2-Ethyl Hexanol	D	448	231	0.88	9.7
2-Ethyl Hexyl Acrylate	D	485	252	—	—
2-Ethyl-3-Propyl Acrolein	C	—	—	—	—
Furfural	C	600	316	2.1	19.3
Furfuryl Alcohol	C	915	490	1.8	16.3
Hexanol	D	—	—	—	—
Isodecaldehyde	C	—	—	—	—
Iso-ictyl Alcohol	D	—	—	—	—
Isophorone	D	860	460	0.8	3.8
Methylcyclohexanol	D	565	296	—	—
2-Methyl-5-Ethyl Pyridine	D	—	—	—	—
Monoethanolamine	D	770	410	—	—
Monoisopropanolamine	D	705	374	—	—
Monomethyl Aniline	C	900	482	—	—
Nitro benzene	D	900	482	1.8	—
Nonyl Alcohol	D	—	—	—	—
n-Octyl Alcohol	D	—	—	—	—
Phenylhydrazine	D	—	—	—	—
Propiolactone	D	—	—	—	—
Propionic Anhydride	D	545	285	1.3	9.5
Tetrahydronaphthalene	D	725	385	0.8	5.0
Tridecene	D	—	—	—	—
Triethylbenzene	D	—	—	—	—
Undecene	D	—	—	—	—
Vinyl Tuolene	D	921	494	0.8	11.0

APPENDIX C

Application Examples

Example #1

Situation: A shed is going to be used for housing hydrogen cylinders. These cylinders are connected via **a** manifold to supply an experiment within the adjacent building. Four solid walls and a roof define the shed. Continuous adequate mechanical ventilation is planned.

Decision Process:

Step 1 (Section VI.A) Is the location a classified location?

Since this area houses hydrogen cylinders connected for use, the area is classifiable.

Step II (Section VI.B) **Is the location Division 1?**

1. Since the hydrogen supply is a closed pipe system, hydrogen is not likely to exist under normal operating conditions.
2. Since adequate procedures and sectional valves limit the release of hydrogen to the interior shed during servicing, hydrogen is not expected during normal operations.
3. Since mechanical damage would be the prime cause of accidental leakage and would not normally introduce simultaneous ignition source, a release with ignition would not be expected.
4. Since the system is adequately piped and ventilated, a hydrogen build up in the shed during normal operations is not expected.
5. Since a lighter than air gas is being used, accumulation at floor level would not be expected.
6. Since the ventilation is arranged to vent from the highest portion of the roof, gas will not accumulate in significant quantities.

Conclusion All of Step II's answers indicate that hydrogen will not normally be present, therefore there are no Division **1** zones.

Step III (Section VI.C) **Is the location Division 2?**

1. Since adequate ventilation is provided constantly to avoid a build up of hydrogen, this item is not applicable
2. Since the flammable gas is subject to leak under abnormal conditions (pipe burst, loose connection), the accidental presence of hydrogen is possible.
3. There is no Division **1** boundary to deal with nor any pockets to trap hydrogen.
4. Although positive mechanical ventilation is used, flammable gases are not normally present. Failure of the ventilation system alone will not lead to the accumulation of a flammable gas/air mixture.

Conclusion Since the accidental presence of hydrogen gas is possible, the location is Division 2.

Step IV (Section VI.D) **What are the boundaries of the classified zone?**

Referring to Figure **13** of Appendix A the-boundaries for the Division 2 equipment are shown. They include the entire interior volume of the shed and within **15** of the ventilation system's output.